NASA Activities in Controlled Environment Agriculture

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Controlled Environment Agriculture for Space--Similar Challenges for Earth

Operational / Economic Goals	Earth	Space
High crop yields	✓ Yes	✓ Yes
Efficient water and nutrient use	✓ Yes	✓ Yes
Energy efficiency	✓ Yes	✓ Yes
Reduced labor cost (crew time)	✓ Yes	✓ Yes
Area and volume efficiency	✓ Yes	✓ Yes
Food safety	✓ Yes	✓ Yes
System mass	No	✓ Yes

Crop Considerations for Space

(some current NASA work in yellow)

- High yielding and nutritious
  - Vit C, B1, Vit K, K content
  - Parathyroid hormone fusion protein (PTH-Fc) for bone mass
- High harvest index (edible / total biomass)
- Dwarf or low growing types
  - 'Pick and Eat' crops for the International Space Station
- Improved photosynthetic efficiency
  - Truncated light antennae for canopy light penetration
  - Use of far-red light for enhanced photosynthesis
  - Ratios of red to blue light
  - Use of solar concentrators for light collection
- Horticultural considerations
  - Planting, harvesting, pollination, propagation
  - Watering systems for µ-gravity
- Environmental considerations
  - Photoperiod, temperature, mineral nutrition
  - Crop tolerance to super-elevated CO_2

LED Studies for plant Lighting

Red...photosynthesis
Blue...photomorphogenesis
Green...human vision

Some Early NASA References on LEDs:

- *Bula et al. 1991. HortSci 26:203-205.*
- *Barta et al. 1992. Adv. Space Res. 12(5):141-149.*
- *Tennessen et al. 1994. Photosyn. Res. 39:85-92.*
- *Goins et al. 1997. J. Exp. Botany 48:1407-1413.*
- *Kim et al. 2004. Ann. Bot. 94:691-697.*

⇒ The use of LEDs for growing plants was patented through NASA funding to the Univ. of Wisconsin in 1990.

Solar Collector / Fiber Optics For Plant Lighting

2 m^2 of collectors on solar tracking drive (SLSL Bldg, NASA KSC)

Up to 400 W light delivered to chamber
(40-50% of incident light)
Takashi Nakamura, Physical Sciences Inc.
(developed through NASA SBIR grant)

Cuello et al., 1998. Life Sup. Biosphere Sci.
Drysdale et al., 2008. Adv. Space Research
Nakamura et al. 2010. Habitation

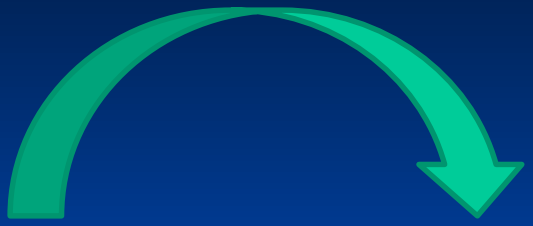
Candidate Crop Testing at Kennedy Space Center

Dwarf Tomato
Red Lettuce and Kale
Dwarf Pak Choi
Dwarf Bell Pepper

Initial crops for
“Pick and Eat”
approach

Dwarf Fruits for Space Crops

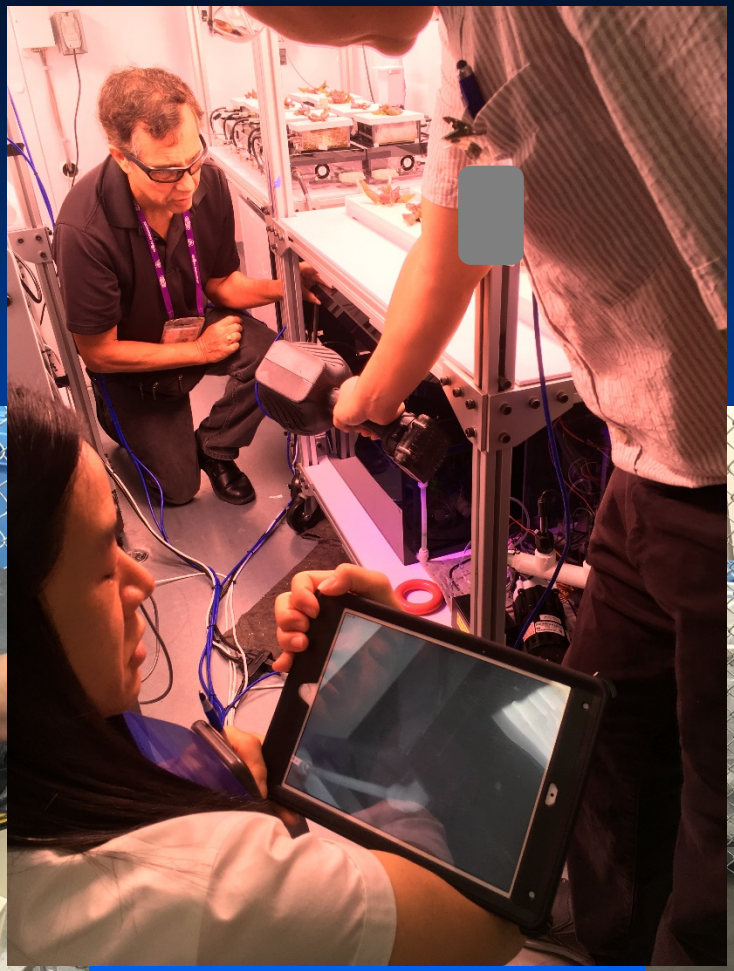
(Prior NASA / ARS collaboration –Ralph Scorza and Chris Dardick, USDA ARS Kearneysville, WV)

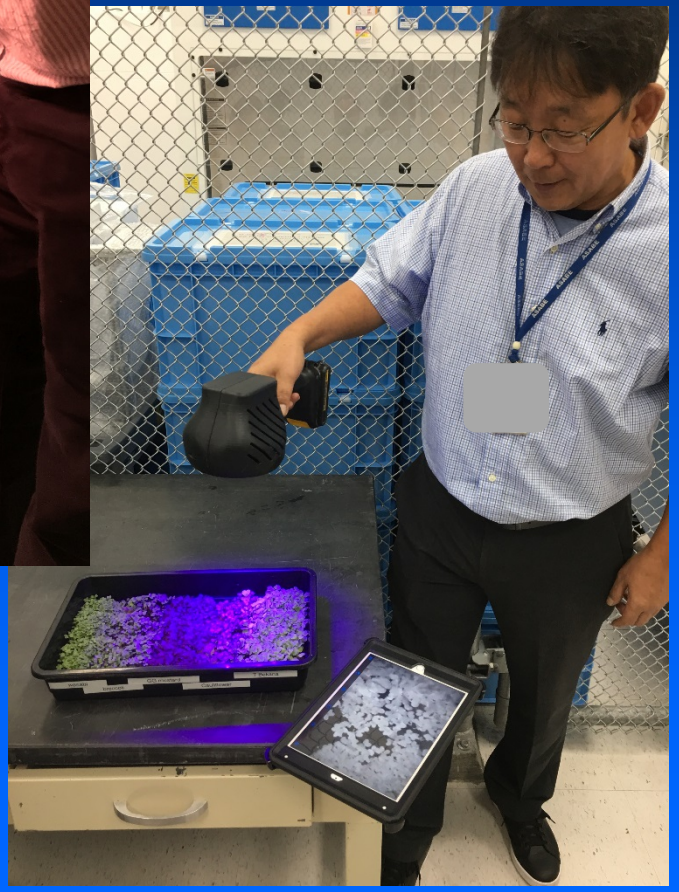


Overexpression of FT flowering gene in plums (USDA / ARS researchers) resulted in dwarf growth habit and early flowering

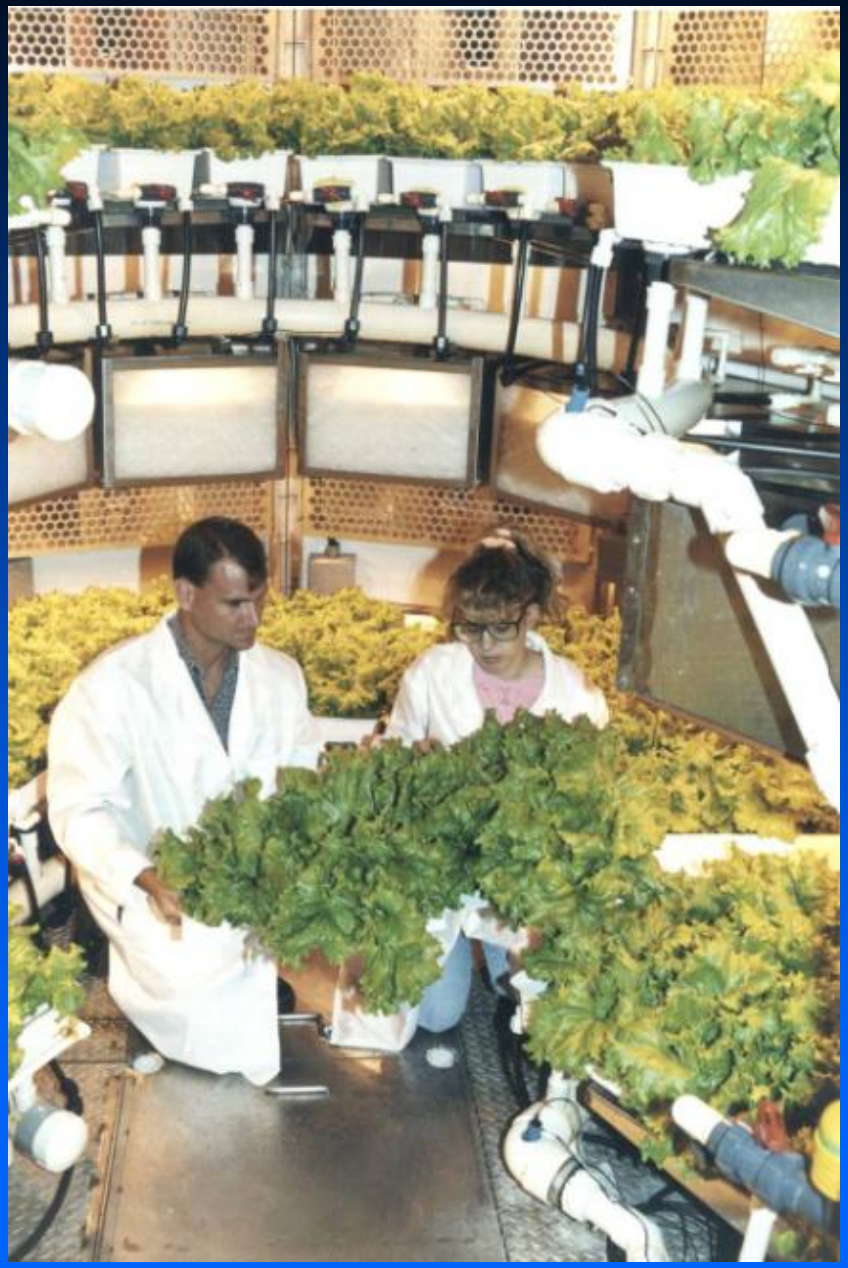
Remote Sensing for Food Safety and Plant Stress Detection

Hyperspectral and Fluorescence Monitoring





Dr. Moon Kim (ARS Beltsville) Visiting NASA Kennedy Space Center, Sept 2018



NASA's Biomass Production Chamber at Kennedy Space Center (1988-2000)

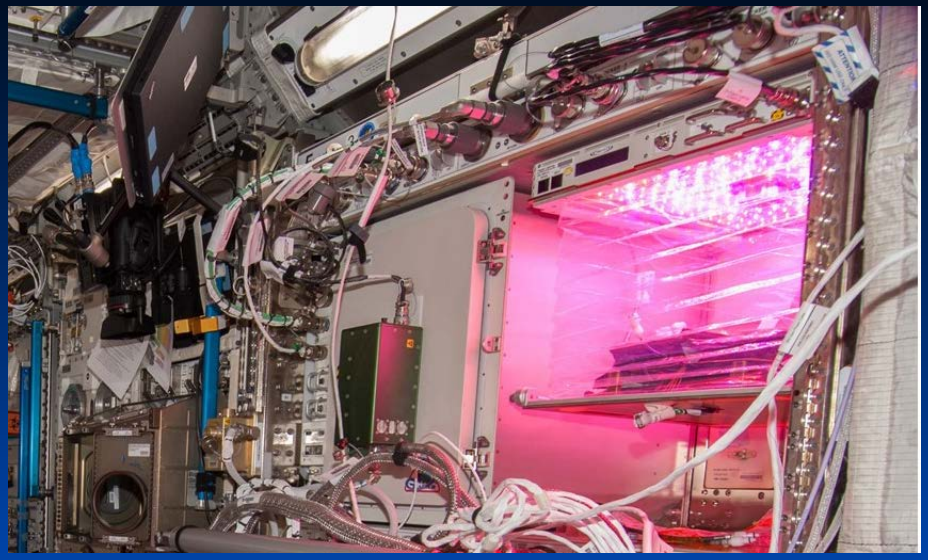
…perhaps the world's first operating "vertical farm"

Potato

(Solanum tuberosum)

Nutrient Film Technique Tested by NASA Now
Used in Several Commercial
Seed Potato Production Facilities

Wheeler et al., 1990. Amer. Potato J.



Getting Started on the International Space Station

Veggie Plant Growth Chamber on ⇑ the International Space Station

Astronaut Joe Acaba Harvesting Mizuna Nov 2017 ⇒

USDA NIFA North Central Extension & Research Activity (NCERA-101) Committee on Controlled Environment Technology

- NASA Funded Academic Participants
  - Bruce Bugbee (Utah State); Peter Ling (Rutgers, Ohio State); Gene Giacomelli (Univ. Arizona); Cary Mitchell (Purdue); Mark Lefsrud (McGill Univ.); Ron Lacey (Texas A&M); Desmond Mortley (Tuskegee); Ted Tibbitts (Wisconsin, retired); Bob Langhans (Cornell, retired); Harry Janes (Rutgers, retired)
- NASA Field Center Participants
  - Dan Barta (NASA JSC); Gioia Massa (NASA KSC); Dave Bubenheim (NASA ARC); Ray Wheeler (NASA KSC); Dave Wilson (NASA ARC); Greg Goins (NASA KSC, Now North Carolina A&T; Cheryl Mackowiak (NASA KSC, now Univ. of Florida); Corey Rutzke (NASA KSC, now Cornell); John Lea-Cox (NASA KSC, now Univ. Maryland); John Sager (NASA KSC retired)
- USDA ARS Employees Affiliated with NASA
  - Dave Fleischer (Beltsville); Steve Britz (Beltsville); Chris Dardick (Kearneysville); Jonathan Frantz (Toledo, now with DuPont Pioneer); Don Krizek (Beltsville, retired);
- USDA Specialty Crops Research Initiative (SCRI)
  - Recent Grant for Energy Efficient Lighting in Controlled Environments with several former NASA PIs:

    Marc van Iersel, (Univ. Georgia); Jennifer Boldt (ARS Toledo); Kale Harbick (Cornell University); A.J. Both (Rutgers); Bruce Bugbee (Utah State); Tessa Pocock (Rensselaer Polytechnic Inst)

Controlled Environment Agriculture in Space

An ARS Station on the Moon ?!